MORTAR

Its Importance to the Mason and Builder in Obtaining Best Results in Brickwork

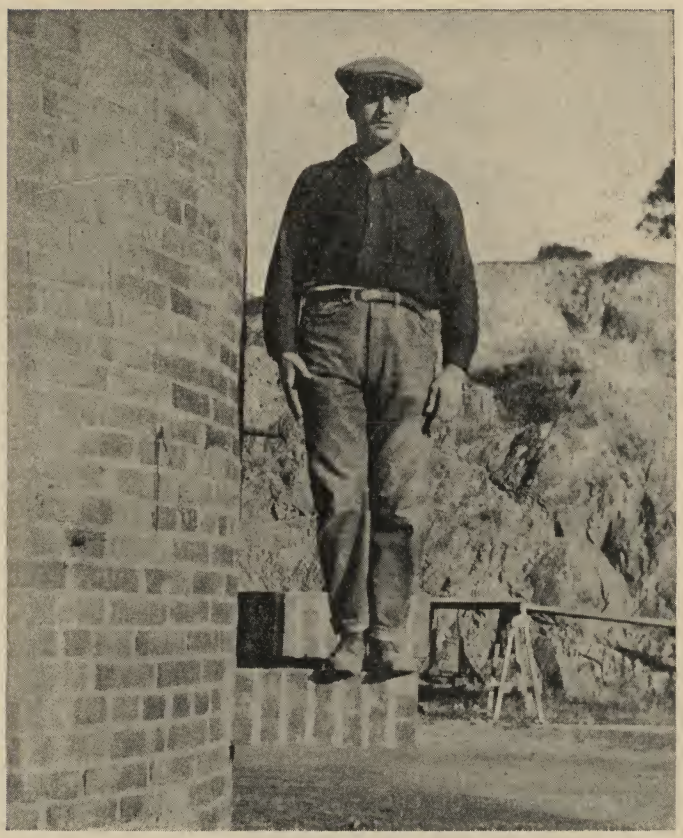
Mortar is the plastic mixture of two or more materials which is used to bind individual bricks together into a solid mass. Its composition, preparation and use is as important in producing good masonry as is the quality of the brick itself.

To be properly equipped in knowledge and skill to produce the highest type of brickwork should be the desire of every one having this work to do.

The Common Brick Manufacturers' Association of America

2121 Guarantee Title Building, Cleveland, O.

Tests Emphasize Mortar Values



The brick beam on which this 196-pound mason stands was built out from the face of a brick smokestack with a cement lime mortar of the proportions of one part Portland cement, one part lime putty and six parts of clean sand. It was supported on trestles for 28 days before this test was made.

MORTAR COMPOSITION

Ingredients of Mortar

Mortar, as generally used in brick masonry, is some mixture of sand, lime, cement and water. It may contain all of these substances or only three of them and the quality as well as the quantity of each substance may vary. The characteristics of each ingredient is given below.

Standard specifications for each of the solid ingredients have been adopted or recommended by the American Society for Testing Materials and may be found in their book of standards. In some large jobs, materials are rigidly specified and carefully and accurately checked. But, in most jobs, the purchase of materials from reliable sources is sufficient guarantee of quality.

It is then only necessary to see that they are properly mixed to produce the desired mortars and to then see that the mortar is properly used to obtain the right kind of brickwork.

CEMENT

The first hydraulic cements used in this country were **natural cements,** manufactured by the calcination of argillaceous limestone containing sufficient silica, alumina and iron oxide to confer hydraulic properties when the burned rock was pulverized and gauged with water. These natural cements, though used for years, have been almost completely replaced by Portland cement, which is much more uniform in composition and behavior.

Modern methods of manufacture produce Portland cement of very uniform physical properties and behavior, although the chemical composition may vary slightly.

Natural cements set more rapidly than Portland cements and are slower in developing strength. The strength of 1:2 natural cement mortar is about equal to that of 1:4 Portland cement mortar.

LIME

The name " lime" is generally used to mean "quicklime". It is also used to embrace "hydrated lime". Chemically, lime is calcium oxide, but in a broader sense it is the class name given to a wide variety of products manufactured by the calcination of limestone, which consists of heating to expel the carbon dioxide. The resulting product is quicklime.

Quicklime is divided into two grades:

(a) Selected.—Shall be well-burned, picked free from ashes, core, clinker or other foreign material.

(b) Run-of-Kiln.—Shall be well-burned, without selection.

Quicklime is shipped in two forms:

(a) Lump.—Shall be kiln size.

(b) Pulverized.—Shall be reduced in size to pass a ¼ inch screen.

Quicklime is divided into four classes:

(a) High-calcium; (b) Calcium; (c) Magnesian; (d) High-Magnesian.

HYDRATED LIME

Hydrated lime is a dry flocculent powder resulting from the de-hydration of quicklime.

Hydrated lime is commercially divided into four classes:

(a) High-Calcium; (b) Calcium; (c) Magnesian; (d) High Magnesian.

The desired properties of hydrated lime are the proper chemical composition, fineness and constancy of volume.

SAND

Sand is obtained from banks or pits, from river beds or from the sea-shore. Pit sand, free from clay or earthy materials is considered best for mortars, although excellent sand is often obtained from river beds.

For convenience, sand is sometimes graded as fine, medium and coarse. Mortar made with coarse sand has the least percentage of voids; made with coarse or well-graded sand it possesses greater strength. Sand passing a No. 4 screen (4 meshes to the inch) is most commonly used in bricklaying. A screen with long vertical slots and narrow horizontal spaces will screen sand effectively and faster than a screen with square meshes.

Sand for mortar must ordinarily be screened. The usual **specification for sand** is that "it shall be clean and free from vegetable matter, loam, large stones and dust." A simple test for cleanliness is to squeeze some wet sand in the hand. If loam is present, the sand will retain its shape; **if not present,** the sand will emit a gritty sound and when rubbed in the palm of the hand will not leave a slimy deposit.

MORTAR COLORS

Natural: Mortar may be colored by using colored sand, such as ground granite or other stone. When the desired shade can be thus obtained, these are preferable to artificial colors, for natural sands and stones usually have a permanent color and do not weaken the mortar.

White joints may be obtained with white sand, ground limestone or marble, using white cement in cement mortars.

The color of the sand, in the finished joint, will, of course, be somewhat modified by uncolored cementing material.

Artificial mortar colors: Great care should be exercised in selecting the proper artificial color. Mortar is strongly alkaline and coloring matter should, therefore, be chemicaly inert or the color may fade or run when in the wall. Mineral colors are preferable.

For cement or cement-lime mortars, **cement** colors should be used; not mortar colors.

The common practice of mixing cement, sand and color in a mortar box with a hoe is not recommended, for uniform batches are difficult to so produce. Wherever possible, it is better to weigh all the ingredients and to measure the water. If the measured ingredi-

ents can be mixed in a concrete mixer, better results will be had.

In any case, the manufacturers directions should be carefully followed.

MIXING MORTAR

The three kinds of mortar commonly used are:

Lime mortar, a mixture of lime putty (or hydrated lime), sand and water;

Portland cement mortar, a mixture of Portland cement, sand and water, and

Cement-lime mortar, a mixture of Portland cement, lime, sand and water.

LIME MORTARS

Since limes are not always of the same quality, a formula for the proper proportions of lime and sand to produce the best mortar is not possible. Experience is about the only, and also the best guide.

SLAKING LIME

Quicklime as such can never be used for structural purposes. It must always be slaked. And since the method of slaking is an important factor in determining the quality of the finished product, the following directions are given as a guide to those who lack experience and as a further protection of the purchaser.

Directions for Slaking: Different kinds of lime vary considerably in the way in which they behave with water. A little supervision over the operation of slaking will amply pay for itself by insuring the production of the greatest possible quantity and the best possible quality of putty. To find out how to slake a new lot of lime, it is safest to try a little of it and see how it works. Since different lots of the same brand of lime vary somewhat, and since the weather conditions at the time have a decided influence, it is wise to try a sample from each lot used, whether familiar with the brand or not.

In a bucket, put two or three lumps of lime about the size of one's fist, or, in the case of granular lime, an equivalent amount. Add enough water to just barely cover the lime, and note how long it takes for slaking to begin. Slaking has begun when pieces split off from the lumps or when the lumps crumble. Water of about the same temperature should be used for test and field practice.

If slaking begins in less than five minutes, the lime is quick slaking; from five to thirty minutes, medium slaking; over thirty minutes, slow slaking.

For quick-slaking lime, always add the lime to the water, not the water to the lime. Have enough water at first to cover all the lime completely. Have a plentiful supply of water available for immediate use—a hose throwing a good stream, if possible. Watch the lime constantly. At the slightest appearance of escaping steam, hoe thoroughly and quickly, and add enough water to stop the steaming. Do not be afraid of using too much water with this kind of lime.

For medium-slaking lime, add the water to the lime. Add enough water so that the lime is about half submerged. Hoe occasionally if steam starts to escape. Add a little water now and then if necessary to prevent the putty from becoming dry and crumbly. Be careful not to add more water than required, and not too much at a time.

For slow-slaking lime, add enough water to the lime to moisten it thoroughly. Let it stand until the reaction has started. Cautiously add more water, a little at a time, taking care that the mass is not cooled by the fresh water. Do not hoe until the slaking is practically complete. If the weather is very cold, it is preferable to use hot water, but if this is not available, the mortar box may be covered in some way to keep the heat in.

MAKING LIME MORTAR

After slaking quick-lime into lime putty, a small quantity of sand is usually added and the mixture put aside in a pile until used. It should stand at least 24 hours before use; a week is better. When required for mortar, the sanded "putty" is shoveled into the mortar box, and "tempered" by adding water and more sand and working to a proper consistency. This is attained when the mortar slides easily off the trowel. Ageing lime paste enables it to carry more sand.

Mortar with Hydrated Lime. Hydrated lime is essentially slaked lime, purchased and delivered in the form of a fine dry powder, instead of a paste. It is sometimes used where space on the job is limited and therefore not room to prepare and store a stock of lime putty; and also when the time and skill necessary to prepare lime putty is not available. It is more quickly and accurately proportioned than lump lime.

Hydrated lime does not require slaking. It is usually mixed with the sand and the water added. When so mixed it does not trowel so easily as mortar made from lime putty, but the working qualities may be improved by allowing the mortar or paste to soak over night. Slaked lime (lime putty) is to be used in preference to hydrated lime, when possible.

Cement mortar. Since Portland cement is of very uniform quality, cement mortar can be mixed in any desired proportions. The proportions recommended and most frequently specified for maximum strength and other desirable qualities are:—one (1) part Portland cement and three (3) parts of sand, by volume, with sufficient water for the proper consistency. A greater amount of sand weakens the mix. A common but dangerous practice is to use more sand than specified in order to lessen the mortar cost, with a result that is sometimes disastrous.

Portland cement mortar is not plastic; it works "short".

Laying brick with Portland cement mortar is slow and more difficult and the bed joints are apt to be not so well filled as with a more plastic mortar.

Cement-lime Mortar. To produce a more plastic or easily worked mortar, lime putty is added to the cement mortar. Any desired amount may be used, but a very good mixture for all-around work, which

is strong and also economical, is one (1) part cement, one (1) part lime and six (6) parts of sand. Such a mixture works smoothly and easily under the trowel and produces brickwork of high strength.

Re-tempering Mortar. Specifications usually require that cement mortars be **not** re-tempered, for the reason that, if the mortar has taken any degree of initial set, the re-tempered mortar is weaker. The quick-setting mortars are most affected. In fact, the loss of strength is roughly in proportion to the speed of mortar setting.

With a slower setting Portland cement, the loss of strength is probably not serious, if the mortar is re-tempered immediately after the initial set. It might, in fact, be re-tempered several times without seriously affecting the tensile strength, but most codes do not permit re-tempering and it is a dangerous practice at best.

With the slower-setting cement-lime or lime mortars, re-tempering is not harmful. A safe guide is that any mortar must not be used after it has passed beyond a state of slight initial set.

The process of re-tempering is to add enough water to restore the desired consistency.

Mortar Colors. The proper methods of using mortar colors are previously described under "Ingredients of Mortar."

USE OF MORTAR

Selecting the Mortar. Three factors should be considered; viz., the required strength and exposure of the brickwork, the cost of the mortar and the degree of plasticity, which latter also affects the speed of laying and hence the cost of brickwork.

It is difficult to lay down any hard and fast rules regarding the kind of mortar for a particular piece of work, but the following may serve as a guide.

It is difficult to lay brick on a bed of soft mortar with a joint ¾ inches thick or over. A ½ inch joint is the more common.

Lime Mortar. Lime mortar may be used for house construction above ground, except where very heavy loads have to be carried on brick piers, or where walls are much cut up by window or door openings, or in very exposed situations. While it is the lowest in cost of all the mortars, it is not recommended.

It should not be used for exterior basement walls subject to a great deal of dampness, unless the wall is thoroughly waterproofed outside, because excessive dampness, if long continued, makes it lose its binding properties.

Straight lime mortar should never be used for fireplaces and flues.

Lime mortar hardens slowly and gets stronger with age.

Natural Cement Mortar. Natural cement mortar may be used in walls or piers carrying heavy loads which will not be exposed to dampness for one month after being laid. It should not be used in very exposed situations.

Portland Cement Mortar. Is recommended for piers or walls which carry heavy loads, for wet or very exposed situations, fire and party walls, work under water, brick footings, sills, chimney and parapet caps, free standing chimneys above roofs, brick steps, cheek walls to steps, brick porch and terrace floors and similar exposed locations and for use in freezing weather. It is also recommended for fireplaces and flues.

It is sometimes used throughout a building. It is the highest in cost of all the mortars.

Cement-Lime Mortar. Cement-lime mortar will set in damp places but is not as weather resistive as Portland cement mortar.

It is recommended for constructing Ideal walls above and below ground.

It is also generally recommended for masonry carrying heavy loads, for all solid residence walls above footings, for fireplaces and flues, and for locations where the work is partially protected, such as veranda posts and piers.

Cement-lime mortar costs less than cement mortar but more than lime mortar. Besides being cheaper than cement mortar in production cost, its greater plasticity permits a higher brick-laying rate and therefore further tends to lower the cost of brickwork.

It should be evident from the foregoing, that, while certain mixtures are recommended as constituting good cement and cement-lime mortar, any proportions of cement and lime and sand may be used. The physical properties of cement-lime mortars of all possible proportions were carefully ascertained by the U. S. Bureau of Standards. We can do no better than quote from the Bureau of Standards paper on "Cement-lime Mortars", by H. V. Johnson.

Ingredients of a Mortar and Consistency

"First, it should be remembered that the mortars under consideration consist, in general, of four ingredients—cement, lime, sand, and water. The proportions of the first three may be varied at the will of the operator. The percentage of water used is fixed within narrow limits by the composition of the mortar and by the fact that the consistency must suit the purpose for which the mortar is used. The effect of the composition of the mortar upon the water required for the same consistency may be expressed by the statement that, in general, lime paste will require much more water than will cement paste, but the water required by each will decline proportionally with increasing additions of sand. As to usage, a mortar of wetter consistency can be used for laying brick than for laying stone or for plastering, and the scratch coat of plaster for metal lath must be stiffer than the scratch coat for masonry.

Composition of a Mortar Affects Its Properties

"A mortar having a high content of cement is characterized by high strength and by a short time of set; it is also fairly workable and shrinks some on drying. One having a high content of lime will

have less strength, will be slower in setting, will be more workable, but will show more shrinkage. The chief characteristic which a high sand content gives to mortar is low shrinkage, but it also results in low strength and in poor workability. An excessive amount of water may permit of easier application of a mortar, but at the expense of strength. The evaporation of this water may be accompanied by excessive shrinkage, or the mortar may be left porous. This high porosity is to be desired if light weight and low thermal conductivity are important; it is not desirable from the standpoint of strength or of permeability".

Recommended Mortar Mixtures

While various proportions of cement, lime and sand may be used, as previously explained, the following are widely used and are recommended for general practice. The proportions are all by volume (not weight).

Cement Mortar. One (1) part cement, three (3) parts of sand.

A very excellent mix is one (1) part cement and three (3) parts of sand, with about 10-15% of the cement replaced with hydrated lime. This mix works easier and is practically as strong as a straight cement mortar. Its cost is so little higher than the cheapest mortar as to be almost negligible in the total cost of brickwork.

Lime Mortar. One (1) part lime, three (3) parts of sand.

Cement-lime Mortar. One (1) part cement, one (1) part lime and six (6) parts sand.

MASONRY

The production of the highest type of masonry requires: first, good mortar properly mixed; second, skilled and intelligent workmanship. There are some important precautions which should be always borne in mind and are therefore given herewith.

Brick should (except in freezing weather) be well wet before laying and **laid while wet.** The greatest wall strength is thus developed. However, hard impervious brick absorb no water and are better laid dry.

Brickwork should be well protected from storm water or snow until the mortar is set; especially from water getting in the top of the wall. If this is done, efflorescence will rarely, if ever, appear.

Brick laid in freezing weather should be dry, not wet.

Mortar should be mixed warm and kept warm until used, by mixing with warm water or in a heated mortar box or both.

Special care should be used to protect the work from freezing or from storm water until the mortar is well set. A good rule is to never leave the top of the wall uncovered or unprotected.

EFFLORESCENCE

A white efflorescence sometimes appears on brickwork, especially in moist climates and damp places. Authorities agree that it is caused by an excess of moisture within the walls which dissolves the soluble salts in the mortar. Water containing these soluble compounds leaches out to the surface where the water evaporates, leaving the salts deposited on the outer surface.

The best remedy is one of prevention; if an excess of moisture and the presence of soluble salts can be avoided, efflorescence will be prevented.

An excess of water is more often due to lack of protection from the weather during construction. Mortar, properly mixed, does not contain excess moisture; that which does the harm is storm water which comes into the top of an improperly protected wall during construction.

While these soluble salts are more commonly found in the mortar, it is thought by some that bricks made from clay containing iron pyrites or burned with sulphurous fuel, may contain these soluble salts in small amounts.

The presence of soluble salts in the mortar may be due to the quality of the sand, to impurities in the lime, sometimes to ingredients or impurities in mortar colors and also to materials in the cement. A careful selection of pure materials for making mortar is therefore very important. And even more important is the protection of brickwork during construction.

As previously stated, efflorescence rarely occurs if the mortar used contains none of these soluble salts. But if their presence is even suspected, it has been found that the salts in the mortar may be neutralized by the addition of barium carbonate, which compound does not affect the bonding properties of the mortar.

Efflorescence may generally be removed by washing the surface with a solution of one part muriatic acid and not less than 15 parts of water. After cleaning, the wall should be well washed down with clear water to prevent the continued action of the acid.

COST OF MORTAR

The cost of any mortar is, of course, the material cost of the ingredients and the labor cost of preparing and mixing.

If the necessary amount of each ingredient and its price in the local market are known, the cost of materials is found by a very simple calculation—multiplying the amount by the unit price.

A laborer with some experience should be able to slake, sand and stack about 1⅜ barrels of lime per hour or 11 barrels in an eight hour day. The time required for mixing and tempering mortar per 1000 bricks is from one to one and one-half hours, depending on the thickness of the mortar joints, for both lime and cement mortar.

One mortar maker, working by hand, should supply five bricklayers; with a mixing machine, one

man can supply 25 or more bricklayers. Assistance in bringing materials to the machine is necessary. It is economical, in any sizable job, to use expert mortar mixers and so keep bricklayers amply supplied with good mortar, as well as with bricks.

The following information should enable one to ascertain the approximate amounts of brick, mortar and labor time for 100 square feet of wall surface of three standard wall thicknesses of the more common types of construction. All quantities are based on the standard brick size of 2¼ inches x 3¾ inches x 8 inches.

USEFUL INFORMATION

Cement: A bag of Portland cement contains 94 lbs. net.

A barrel of Portland cement contains four bags, or 376 lbs. net.

When packed, Portland cement weighs about 108½ lbs. per cubic foot; when loose, 92 lbs. per cubic foot.

Portland cement should be kept from dampness. Keep empty bags dry, for allowance is made for bags returned in good condition.

A cubic foot of cement paste requires about 94 lbs. of cement.

Lime: A bushel of lump lime contains from 75 to 85 lbs. net.

A cubic foot weights from 60 to 65 lbs.

A 180-lb. barrel contains about 3 cubic feet.

A 280-lb. barrel contains about 4¾ cubic feet.

The average amounts of lime putty obtained from lump lime is as follows:

From one bushel lump lime, 3 cu. ft. putty.

From one 180-lb. barrel, 7 cu. ft. putty.

From one 280-lb. barrel, 11 cu. ft. putty.

Hydrated Lime: One cu. ft. weighs about 40 lbs.

One paper package contains about 50 lbs. net.

One cloth package contains about 100 lbs. net.

One 100-lb. package makes about 2.28 cu. ft. of lime paste.

Sand: A cu. ft. weights about 100 lbs.

Is usually sold by the yard (cubic yard) which contains 27 cu. ft.; sometimes by the ton (2000 lbs.) which contains about 20 cu. ft.

Brick: The standard size of building brick is 2¼ in. x 3¾ in. x 8 in., but slight variations in these dimensions are unavoidable and permissible.

The average brick weighs about 4½ lbs.

One thousand (1000) brick closely stacked occupy about 56 cu. ft. of space.

BRICK NECESSARY FOR 100 SQUARE FEET OF WALL SURFACE

The approximate amounts of standard-size brick necessary to build 100 square feet of wall of the three standard thicknesses are given below. From these data may be **estimated** the amount and cost of mortar for any specific piece of work. For more complete and detailed data, the reader is referred to our book "BRICK—HOW TO BUILD AND ESTIMATE".

MATERIALS REQUIRED FOR MAKING MORTAR

The quantities of each material given are the approximate amounts necessary to make 100 cubic feet of mortar of the recommended mixes. The amounts for any quantity other than 100 cubic feet can be readily calculated by multiplying the quantities given herewith by the desired number of cubic feet and dividing the quotient by 100 (or by pointing off two decimal places from the right, which is the same thing.)

Lime Mortar: (1 part lime and 3 parts sand) will require about:

5—180-lb. barrels of lump lime, or

29—50-lb. sacks of hydrated lime and

4—cu. yds. of sand.

Cement-Lime Mortar: (1 part cement, 1 part lime and 6 parts sand) will require about:

13—94 lb. sacks of cement,

2—180-lb. barrels lump lime, or

15—50-lb. sacks hydrated lime and

4—cu. yds. of sand.

Cement Mortar: (1 part cement and 3 parts sand, with 1/10 of the cement, by weight, replaced by dry hydrated lime or its equivalent in lime putty), will require about:

33—94-lb. sacks of cement,

1.2—180-lb. barrels of lump lime, or

7—50-lb. sacks of hydrated lime, and

4—cu. yds. of sand.

Cement Mortar: (1 part cement and 3 parts sand) will require about:

37—94-lb. sacks of cement, and

4—cu. yds. of sand.

BRICKS AND MORTAR REQUIRED

For 100 Square Feet of Wall Surface

All Joints Assumed to be ½ Inch Thick

Kind of Wall	Wall Thickness Inches	Number of Bricks	Cu. ft. of Mortar	Remarks
Exterior solid wall, in all bonds. All joints filled with mortar. Every 5th course a header.	8	1233	20	This type construction best, but uses maximum amount of mortar.
	12	1850	32	
	16	2465	44	
Solid walls in common bond. Exterior 4 inch laid with all joints filled; remaining thickness laid with full bed, brick touching end to end, vertical space between each 4 inch thickness filled with mortar. Every 5th course a header.	8	1271	20	Type of wall sometimes built. Not recommended for heavy loads.
	12	1926	32	
	16	2580	44	
Same as above, but with vertical space between each 4 inch thickness left open.	8	1271	14	
	12	1926	20	
	16	2580	26	
Exterior Ideal all-rolok wall	8	904	8	Methods of constructing Ideal hollow walls shown in detail in our book "Brick—How to Build and Estimate".
For heavy type wall.	12½	1431	13	
For lighter type wall.	12½	1330	12	
Exterior Ideal Rolok-bak wall.				
Flemish headers every 6th course.	8	1052	12	Construction details shown in "Brick—How to Build and Estimate".
Flemish headers every 3rd course.	8	1078	12	
Flemish headers every 6th course.	12½	1544	15	
Flemish headers every 3rd course.	12½	1578	15	